# NOvA Update

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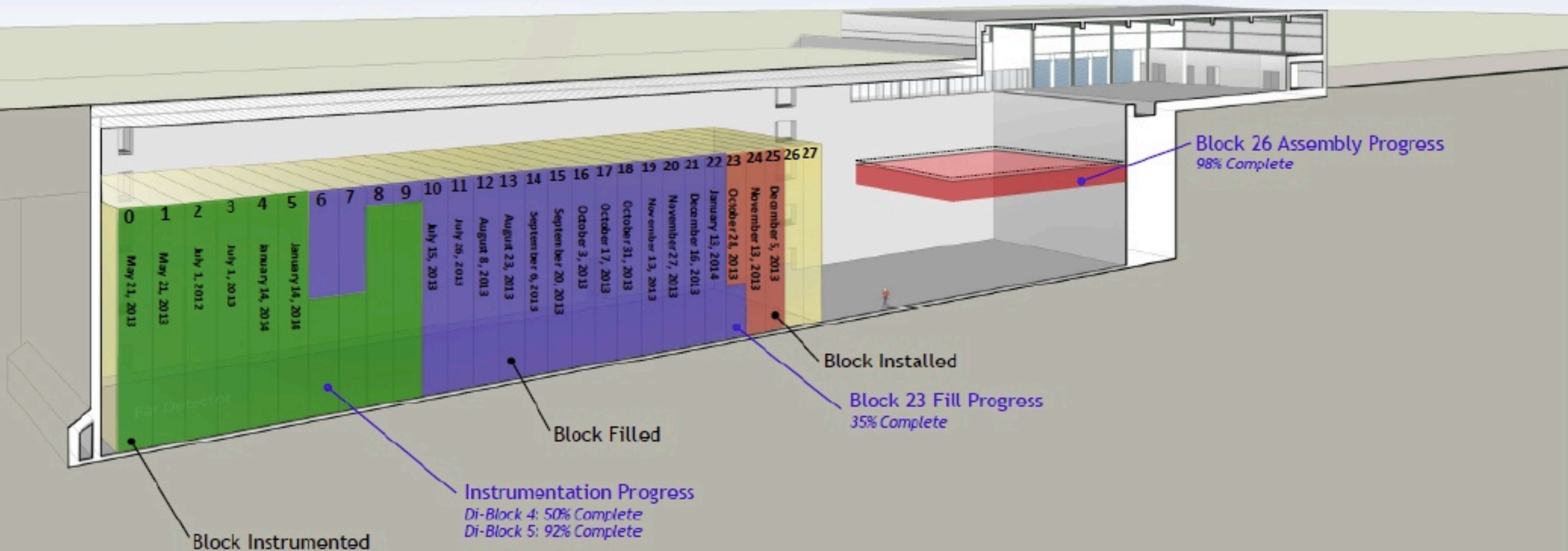
**Fermilab PAC**
**January 22, 2014**

# Update since last PAC meeting

- Far detector construction and installation progress
- Avalanche Photo Diode Status
- Near detector schedule and progress
- Start of far detector operations
- First look at cosmic ray data
- Expectations for first neutrinos

# Far detector construction / installation progress
# 20 January 2014

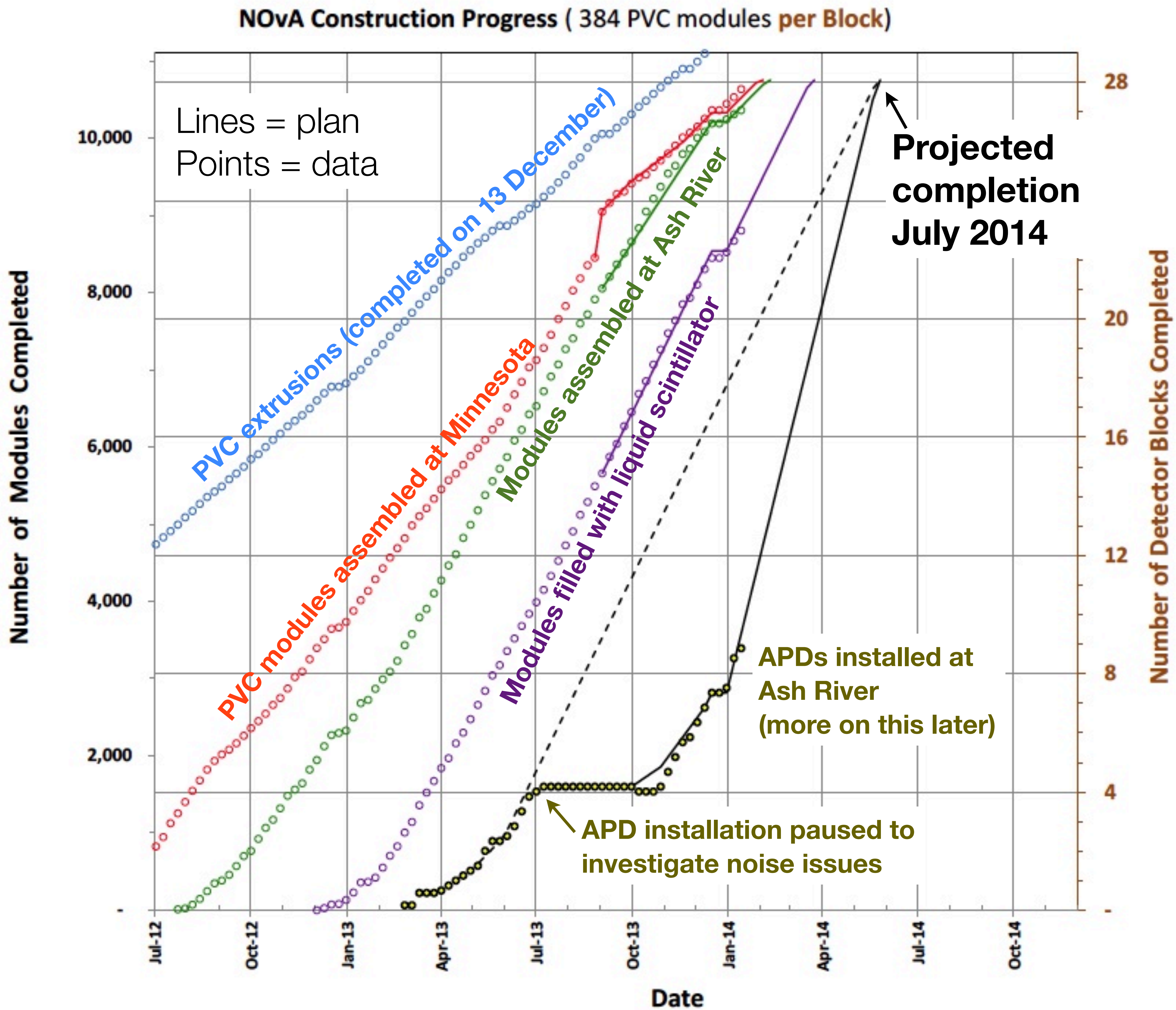



**14 kilotons = 28 NOvA Blocks**

*26 blocks of PVC modules are assembled and installed in place*

*23.35 blocks are filled with liquid scintillator*

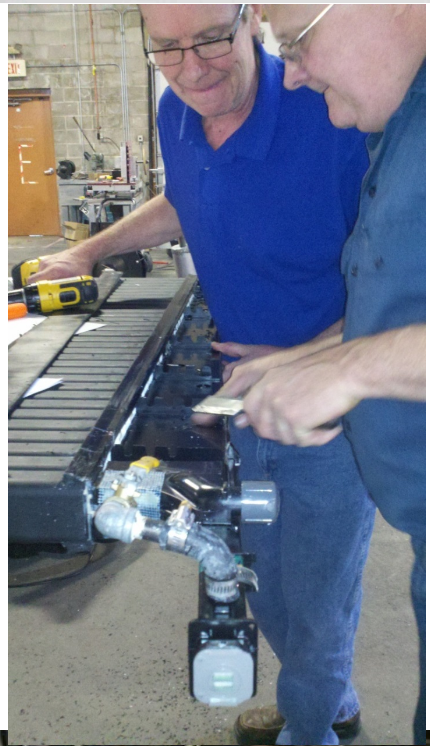
*8.84 blocks are outfitted with electronics*



NOvA Construction Progress ( 384 PVC modules per Block)
Lines = plan
Points = data
PVC extrusions (completed on 13 December)
PVC modules assembled at Minnesota
Modules assembled at Ash River
Modules filled with liquid scintillator
Projected completion July 2014
APDs installed at Ash River (more on this later)
APD installation paused to investigate noise issues
Number of Modules Completed
Number of Detector Blocks Completed
Date
10,000
8,000
6,000
4,000
2,000
-
28
20
16
12
8
4
-
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14

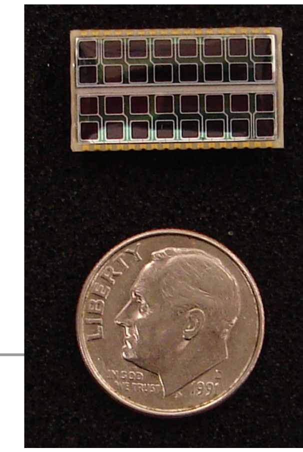

10,000

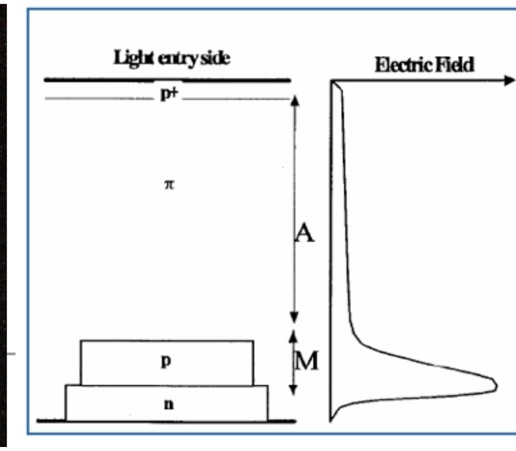

21
FOOTBALL
Reese's
MODULE
10,000



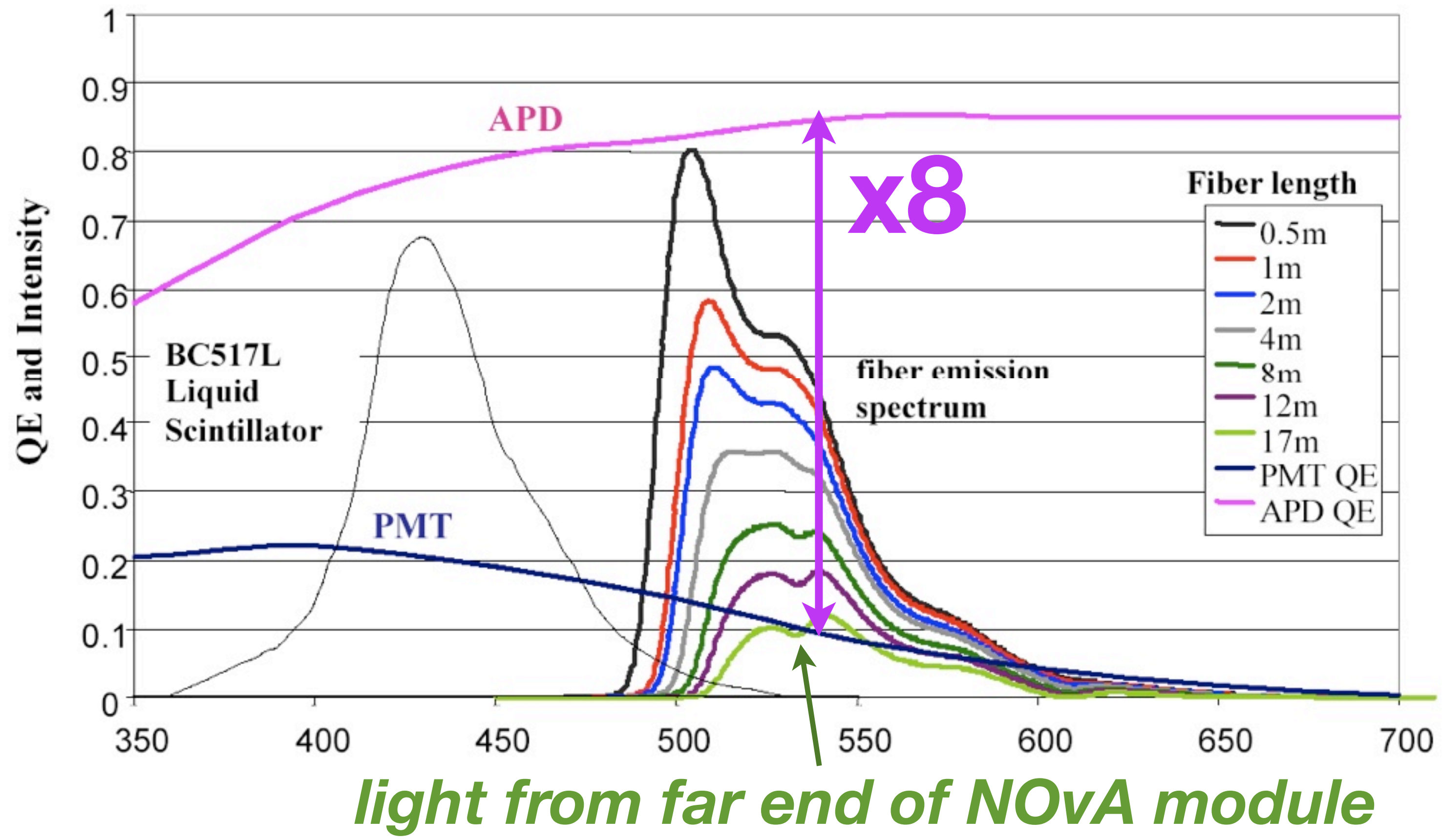

NDSU

# *Avalanche Photo Diodes (APDs) Background*



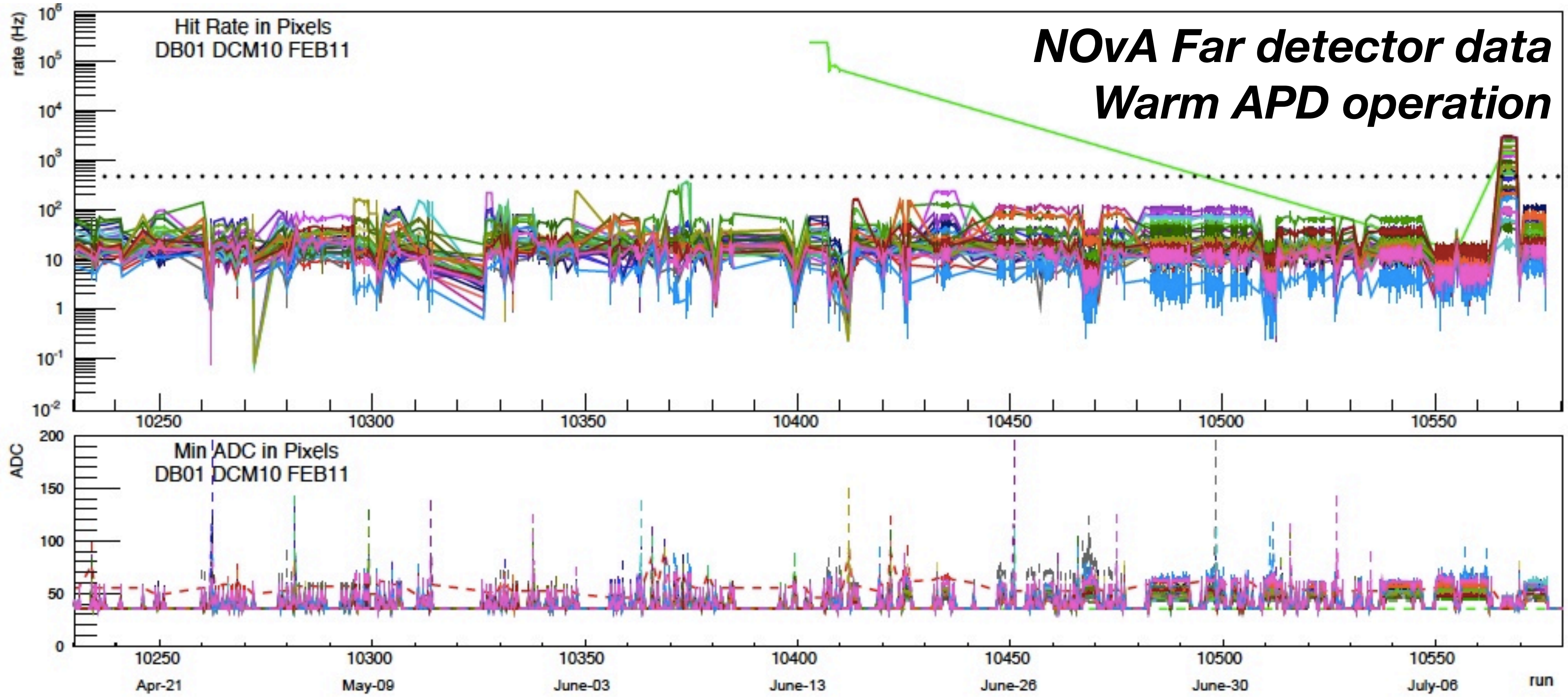



- APDs are an enabling technology for NOvA. Their high quantum efficiency allows us to see light at the end of 15 m long modules.
- They must be run at -15 C (waste heat removed by water system).
- Silicon surface must be kept clean and dry - achieved by flowing dry air across surface
- Standard procedure for Hamamatsu is to coat the silicon surface using silicone but their coating could not meet our specifications for uniformity and optical cross-talk.

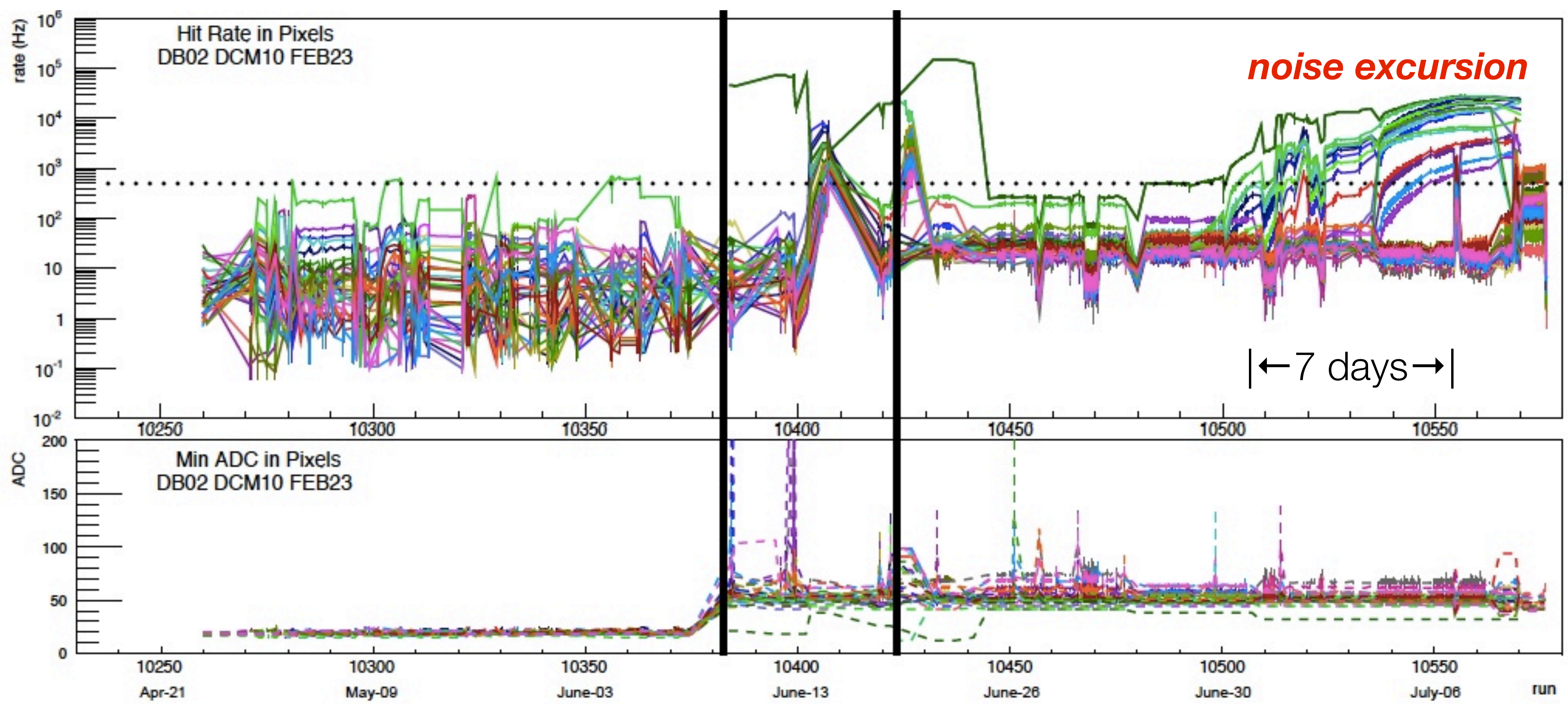



- Following Hamamatsu's recommendation, we tried operating prototype detector (NDOS) with bare silicon APDs. That proved too fragile and we tested other coating options.
- Identified parylene - a clear epoxy that is vapor deposited by a third party - as best coating option and after tests at Fermilab and Caltech proceeded with APD production for far detector
- Many APDs in early samples of parylene coated APDs showed bad long term noise behavior during warm operation. Halted production in July 2013 and began battery of tests at Fermilab and Caltech.

A good APD. Noise rates between 10-100 Hz/ pixel

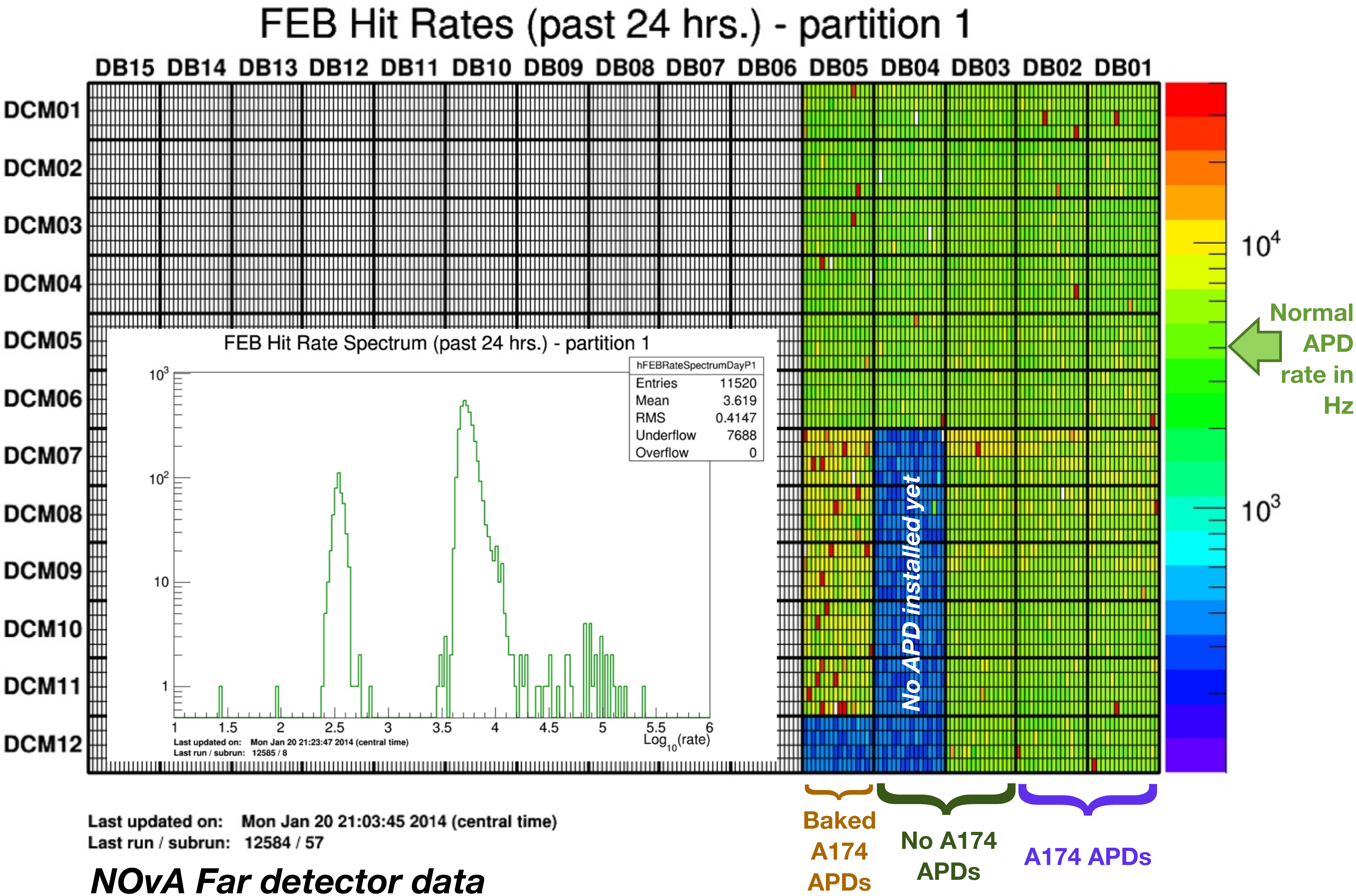



A noisy APD. Noise rates climb to ~1000 Hz on many pixels over period of hours to days



# *Avalanche Photo Diodes (APDs)*

- Following tests conducted during summer of 2013, noise problem is linked to a bonding agent (“organosilane”, aka “A174”) applied to APDs prior to parylene coating.
- Coater removed A174 from their process and we subjected pieces to tests of bond strength and rapid temperature cycling. The bond was judged strong enough and no noise issues emerged.
- Tested baking A174-coated parts to see if recovery of these parts is possible.
- Resumed APD production in October and installed “no-A174” parts and baked A174 parts on detector. These pieces having been running cold ~24/7 for 1-3 months and we’ve been monitoring their performance.



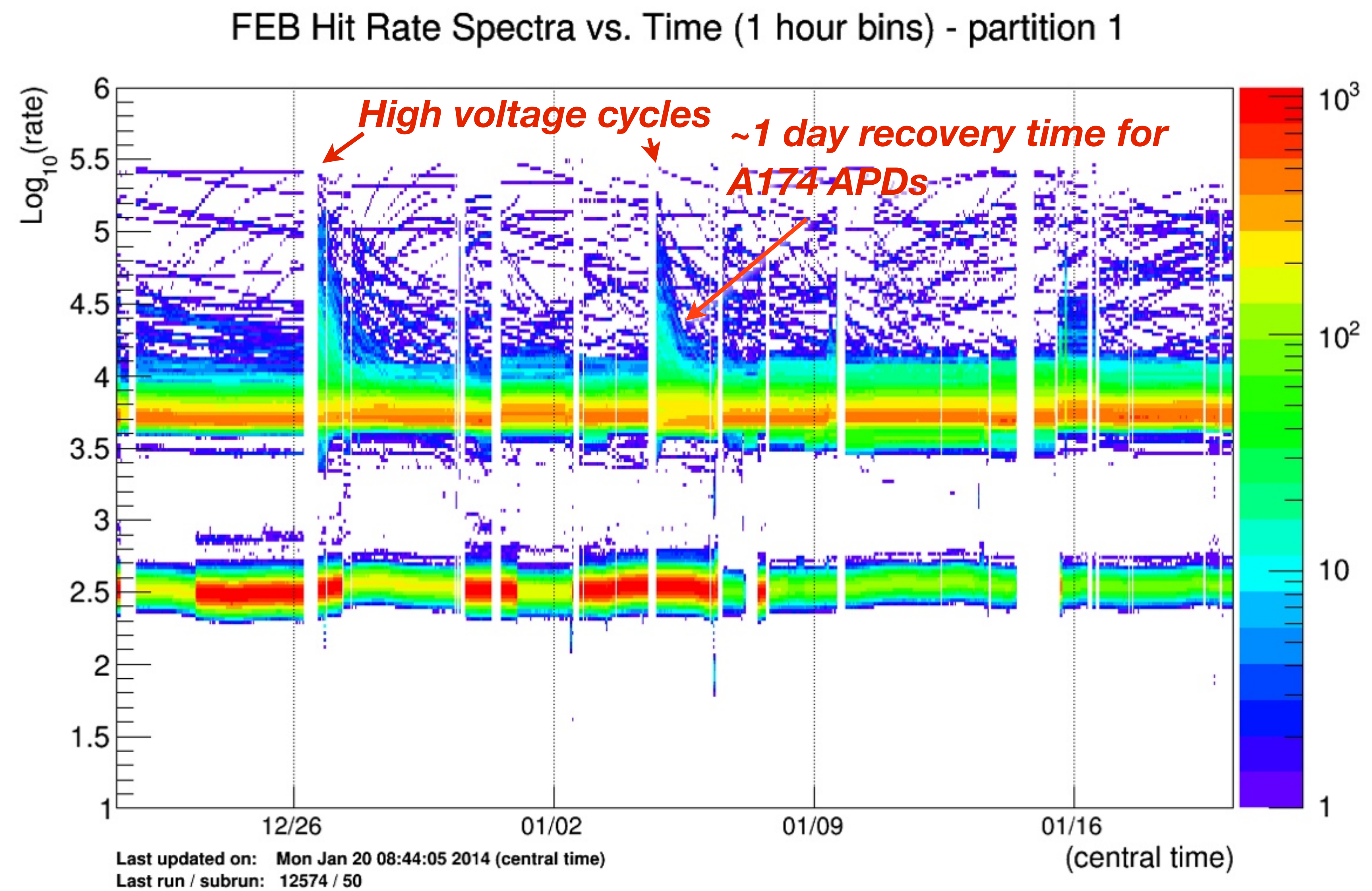

***NOvA Far detector data***
***APDs running in cold state***

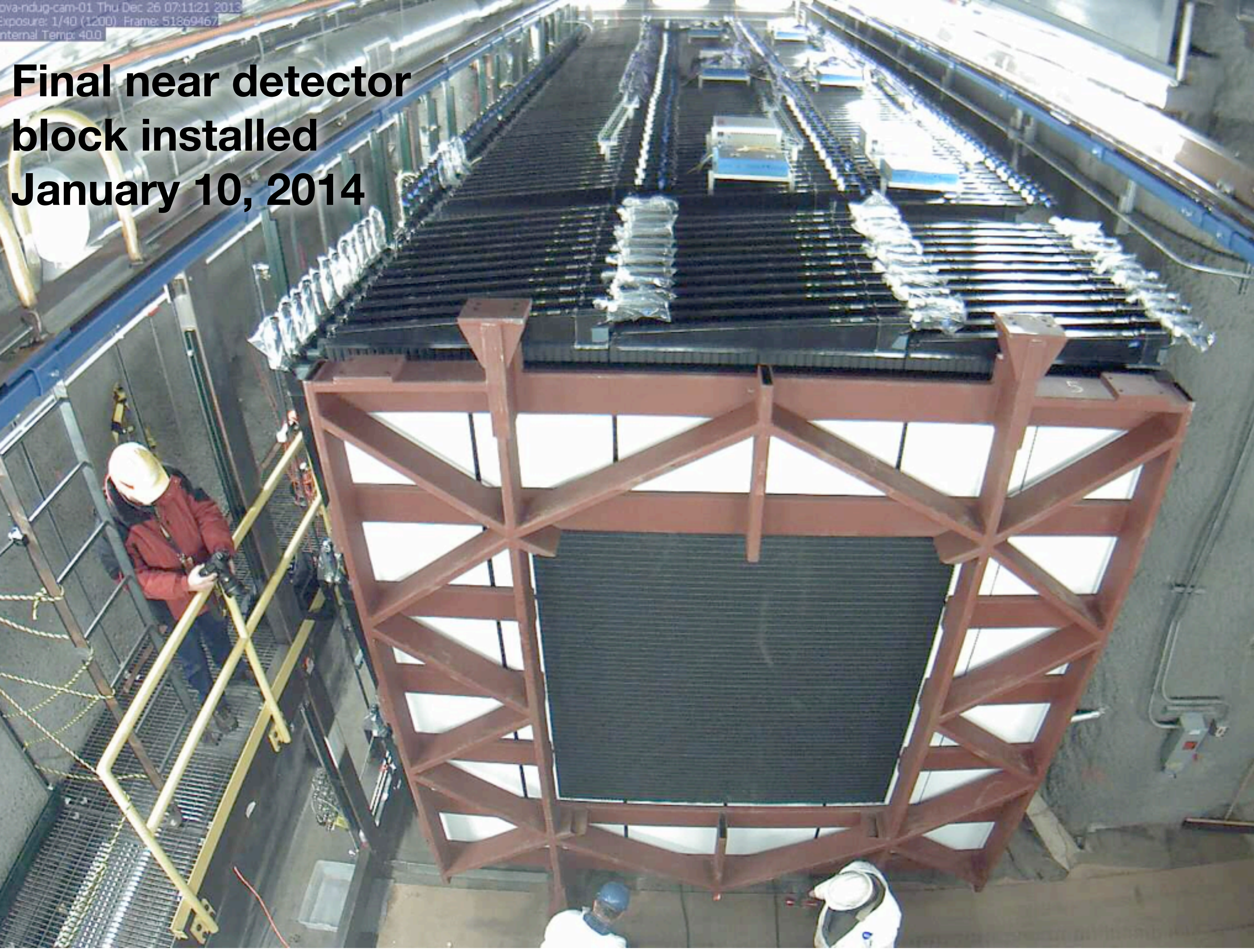
***Each diblock contains 768 APDs***

# APD Summary

- When running cold, ~95% of "A174 APDs" run with acceptable noise levels. Iteratively replacing outliers we have **>99% of the "A174 APDs" running within specifications on diblocks 1 and 2.***
- Baking the "A174 APDs" seems to have no effect when applied in large batches
- **>99% of the "no A174 APDs" run within specifications** on first installation.
- Proceeding with installation of "no A174 APDs" at far detector

✳ A174 APDs take long time to recover after high voltage power is cycled. "No A174 APDs" do not show this behavior. This recovery time is unacceptable at the far detector and we are pursuing options with the project to purchase enough "no A174" APDs to eventually bring the entire far detector to a "no A174" state.





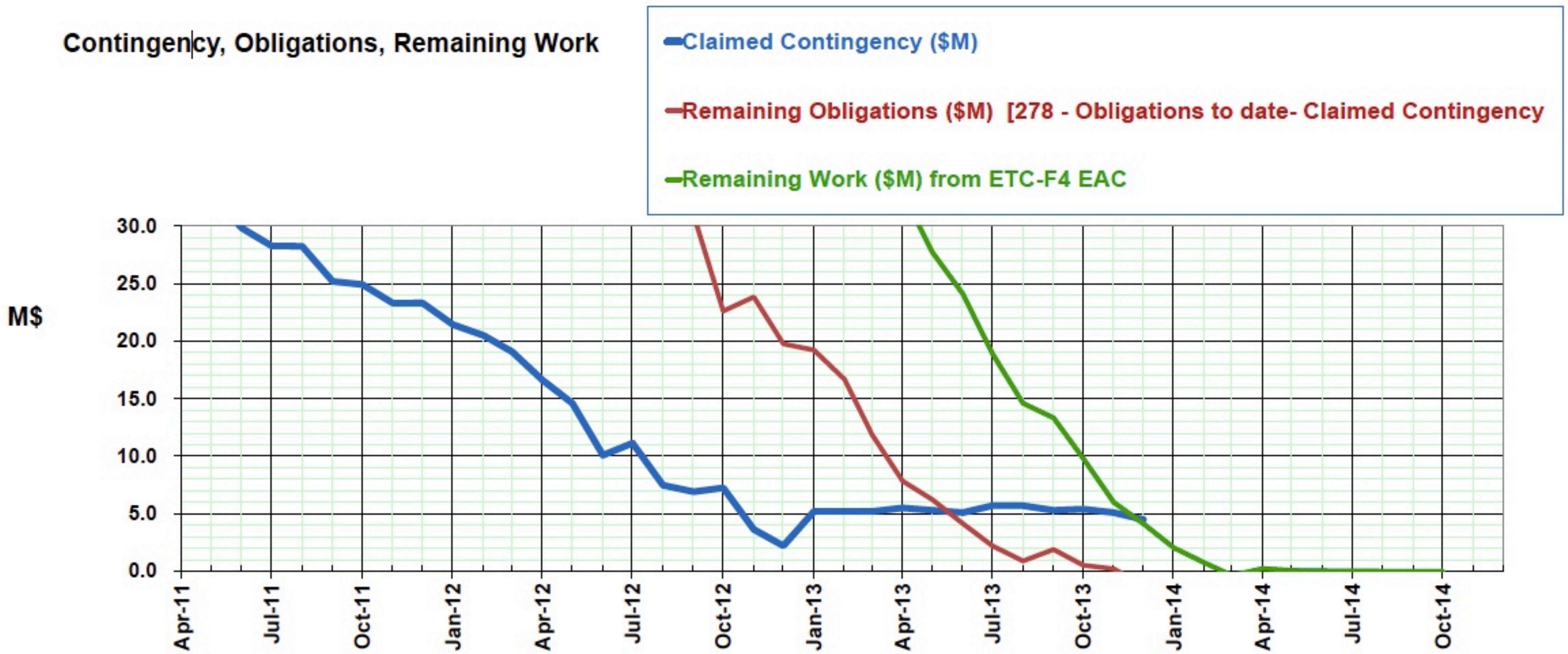

**Final near detector block installed January 10, 2014**

# *Near detector filling and instrumentation schedule*

| Block | Modules from Minneapolis | Block Assembly Complete | Block Installed Under-ground | Scintillator fill complete | FEB installed | APD installed |
|---|---|---|---|---|---|---|
| Muon catch-er | 24Apr2013 | 02Aug2013 | 02Aug2013 | 31Jan<br>Working ORC list, hope to start week of 21Jan | Nov - Jan,<br>28Mar | April |
| 1 | 21May | 14Aug | 21Aug | 07Feb | 04Apr | April |
| 2 | 20June | 12Sept | 25Sept | 14Feb | 04Apr | April |
| 3 | 08Aug | 01Oct | 07Oct/09Oct | 21Feb | 11Apr | April |
| 4 | 17Sept | 28Oct/14Oct | 04Nov/21Oct | 28Feb | 11Apr | April |
| 5 | Sept 24 | 05Nov/28Oct | 11Nov/05Nov | 07Mar | 18Apr | April |
| 6 | 11Oct/01Nov | 21Nov/08Nov | 25Nov/14Nov | 21Mar | 18Apr | April |
| 7 | 01Nov/13Nov | 12Dec/22Nov | 16Dec/27Nov | 28Mar | 25Apr | April |
| 8 | 22Nov/20Dec | 08Jan/06Jan | 08Jan/10Jan | 11Apr | 25Apr | April |

**FEB5 delivery is critical path. Hoping to interleave delivery to advance schedule.**

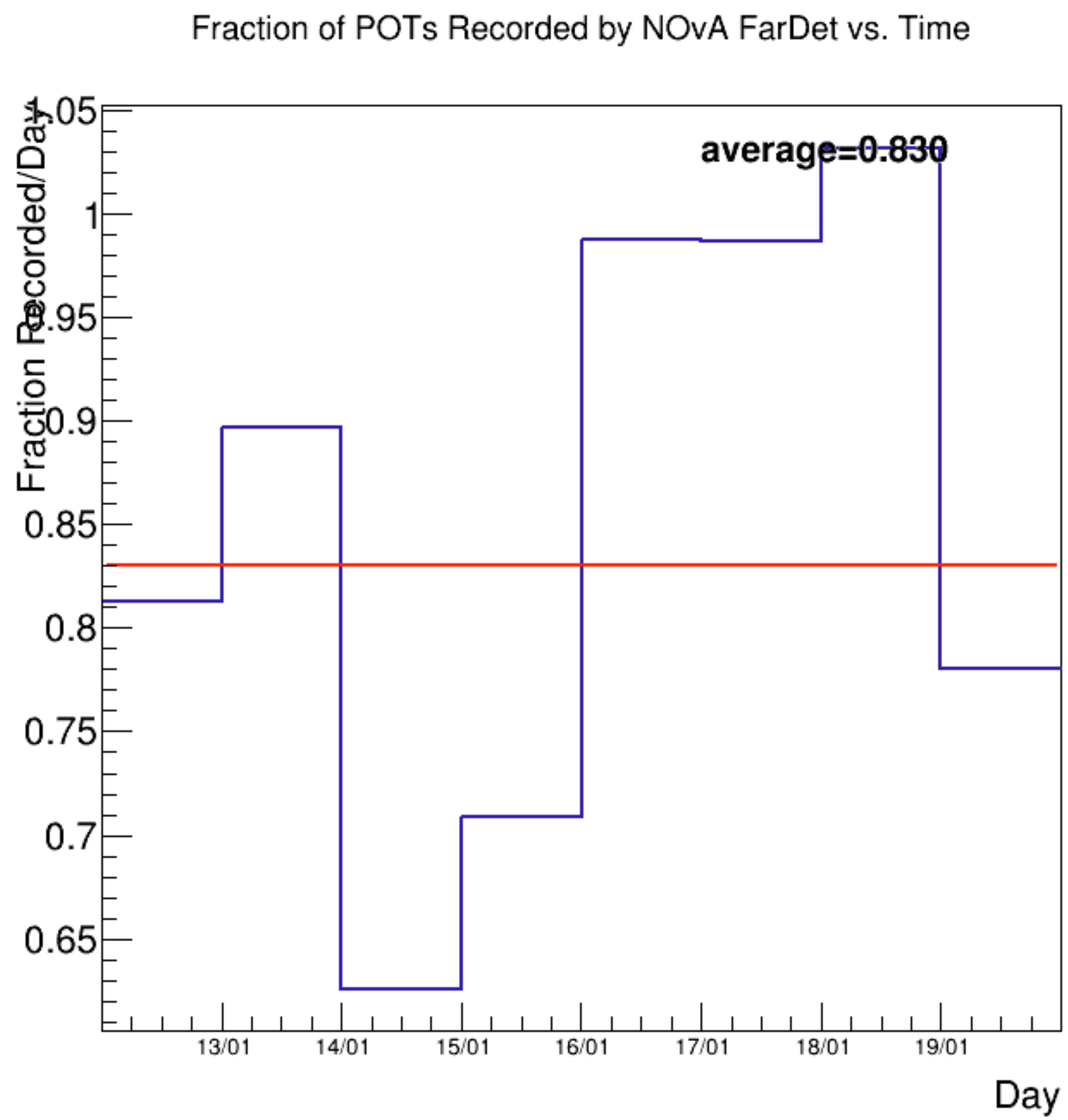
# Project contingency usage and plans



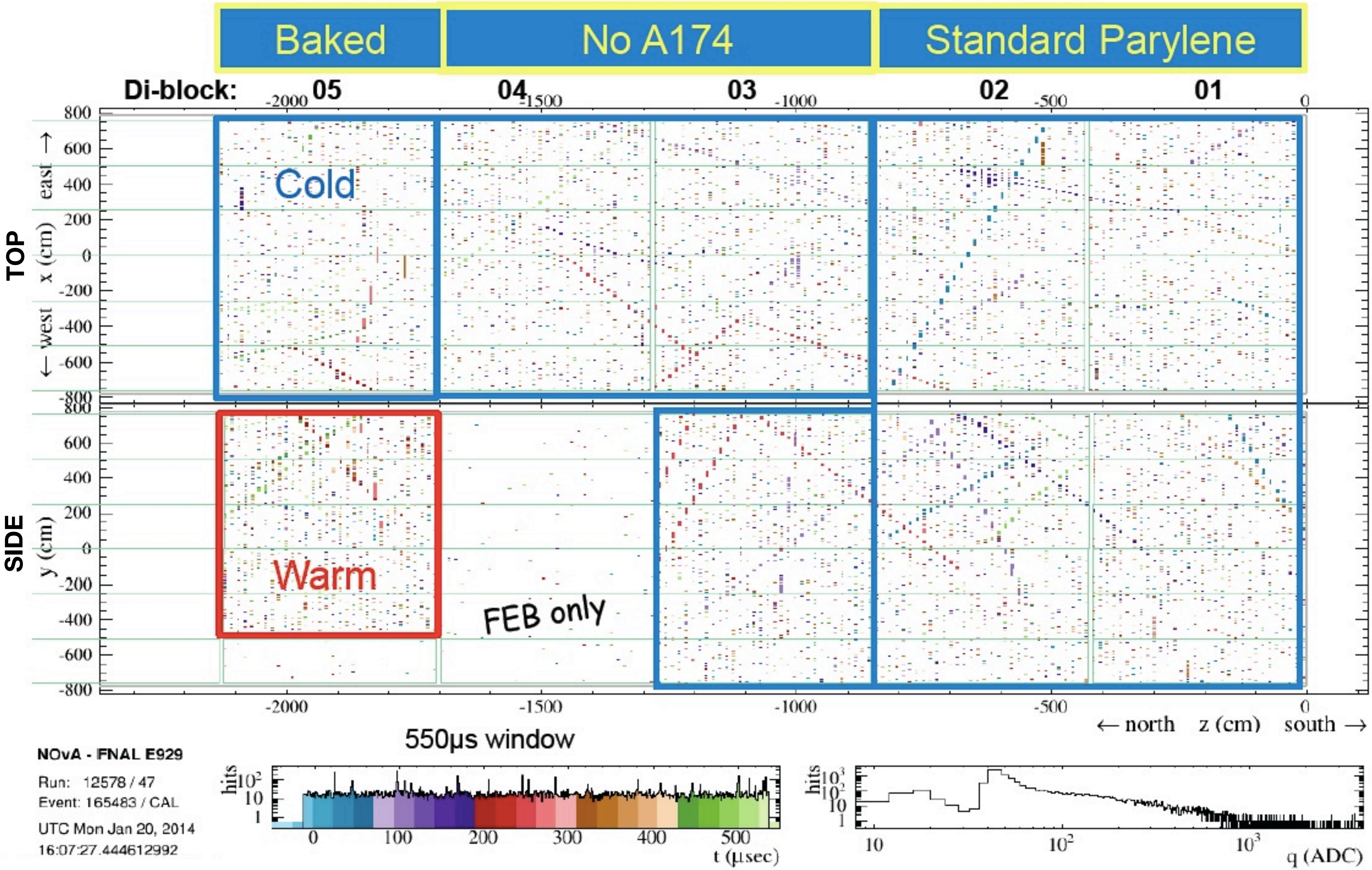

| | |
|---|---|
| $0.825M | Additional 2500 APDs |
| $0.136M | Test beam blocks |
| $0.5M | Additional far detector overburden |
| $3.03M | Returned |
| $4.5M | Total |

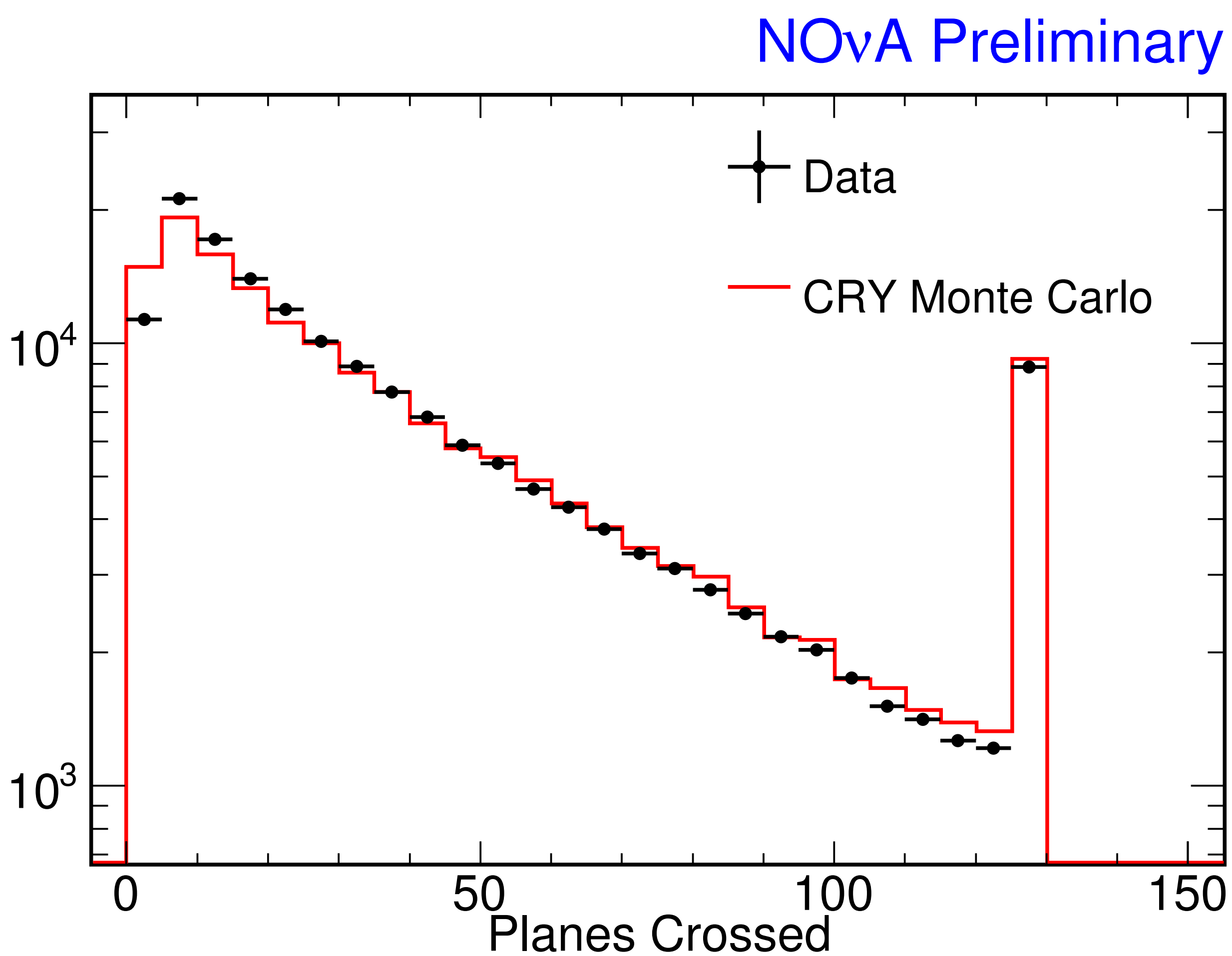
# Operations

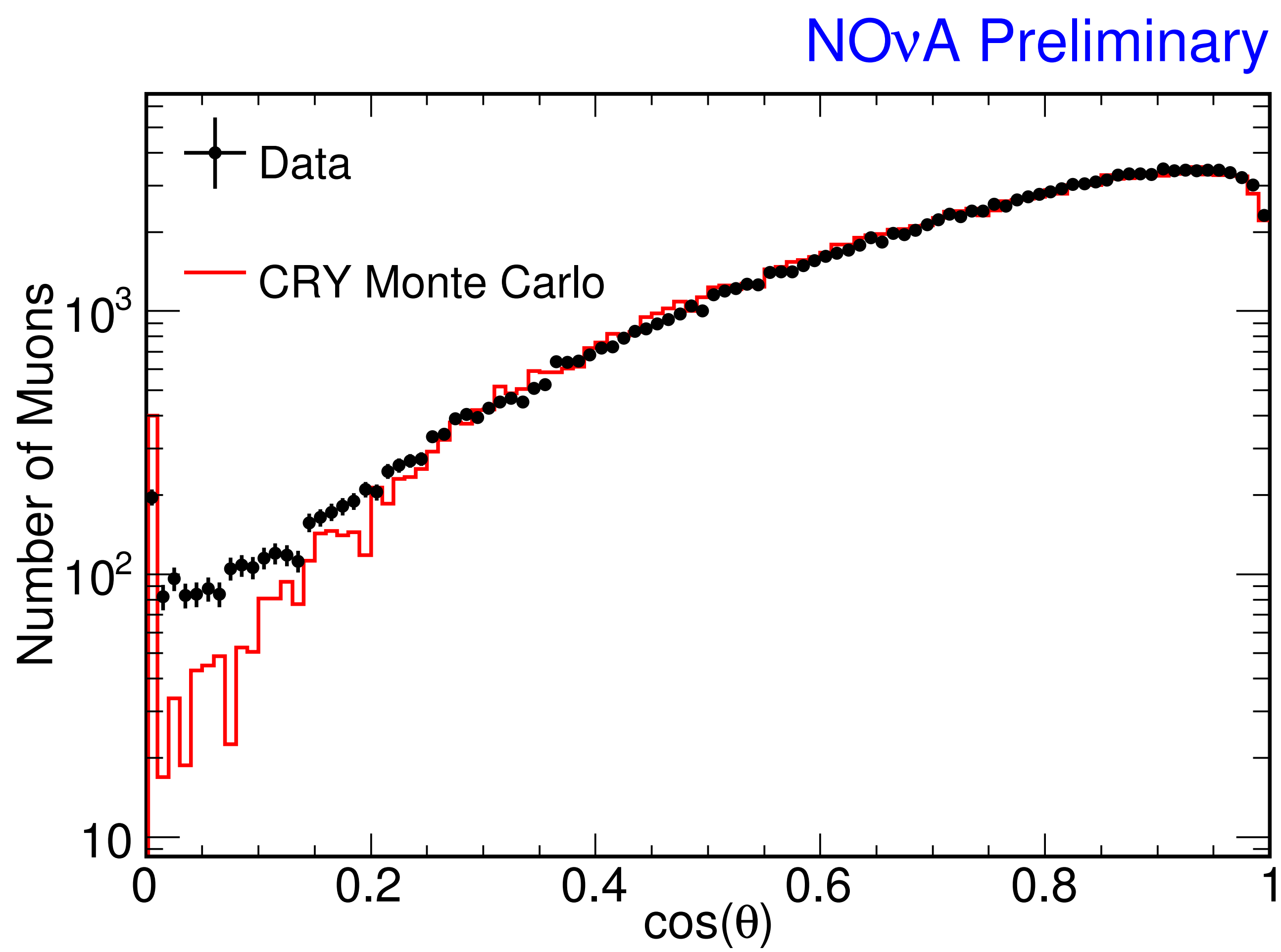
- We currently operate shifts 24/7 in Wilson Hall on 12th floor
- Typical shift plan:
    - Monday - Thursday: Assist installation crew with check out of new and repaired hardware. Try to run completed diblocks stably between check out runs.
    - Friday - Sunday: Run with completed portions of detector trying to maximize uptime.




Week ending January 20th

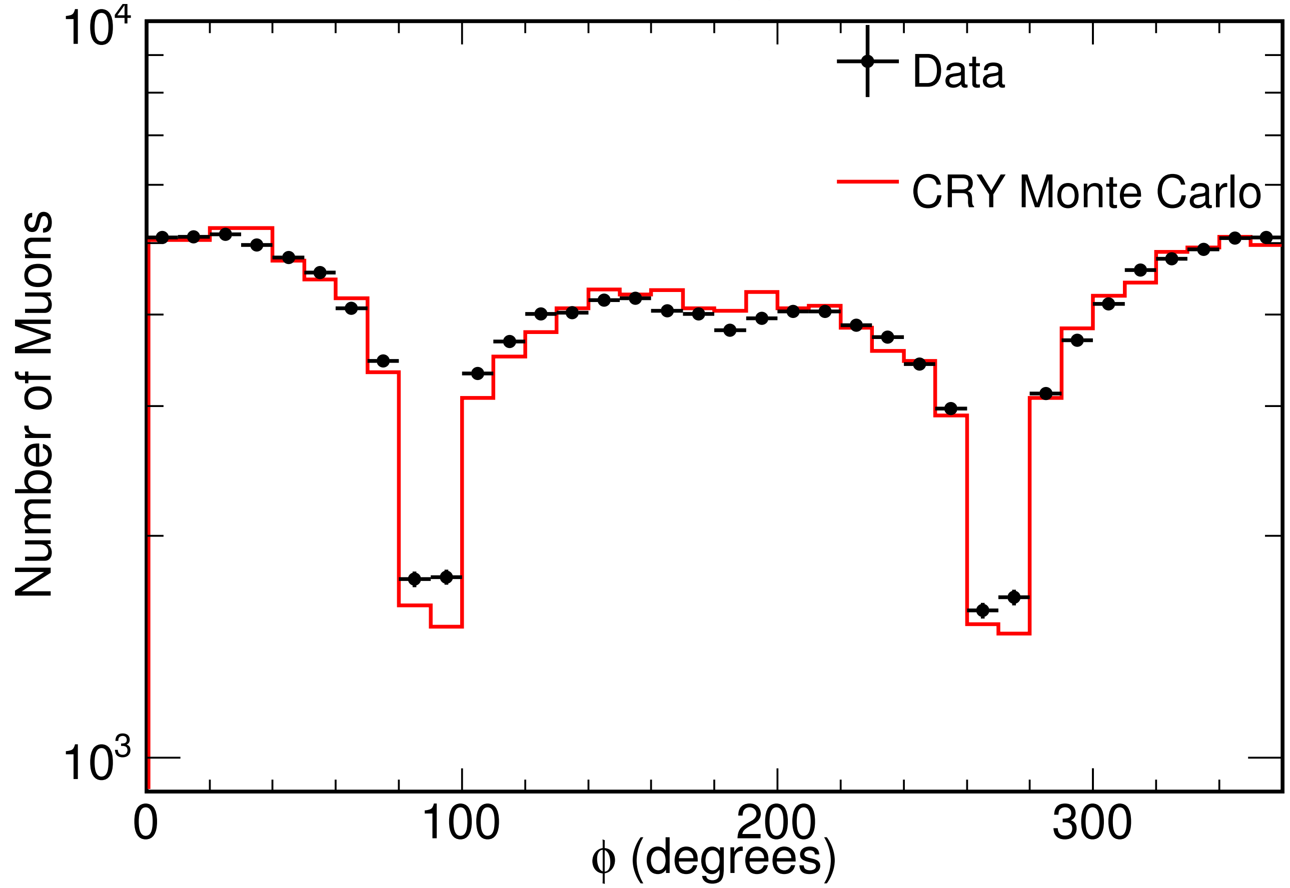

Baked
No A174
Standard Parylene
Di-block: 05 04 03 02 01
TOP
x (cm)
← west east →
Cold
SIDE
y (cm)
Warm
FEB only
← north z (cm) south →
550μs window
NOvA - FNAL E929
Run: 12578 / 47
Event: 165483 / CAL
UTC Mon Jan 20, 2014
16:07:27.444612992
hits
t (μsec)
q (ADC)



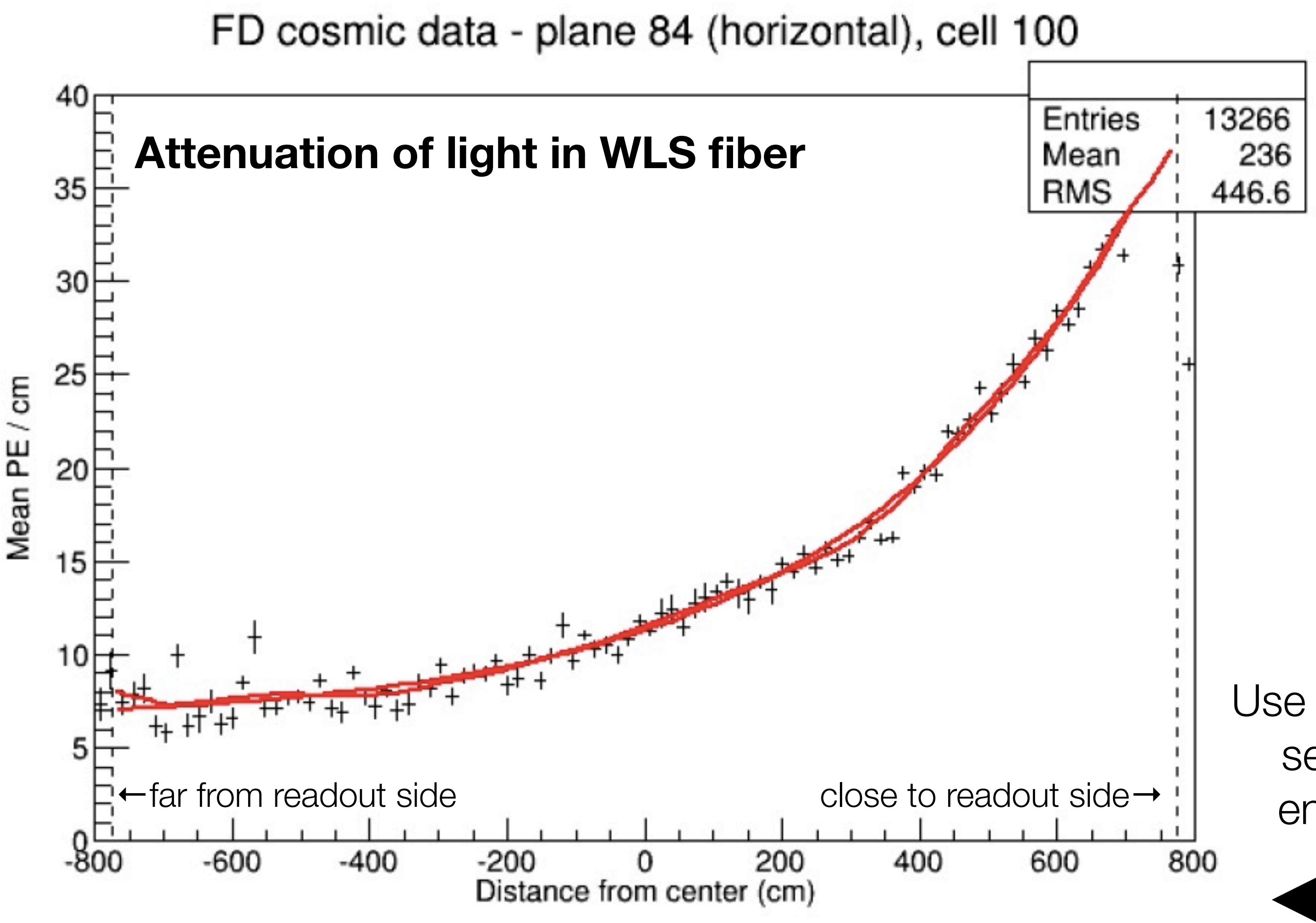




# ***Cosmic-ray muon rates***

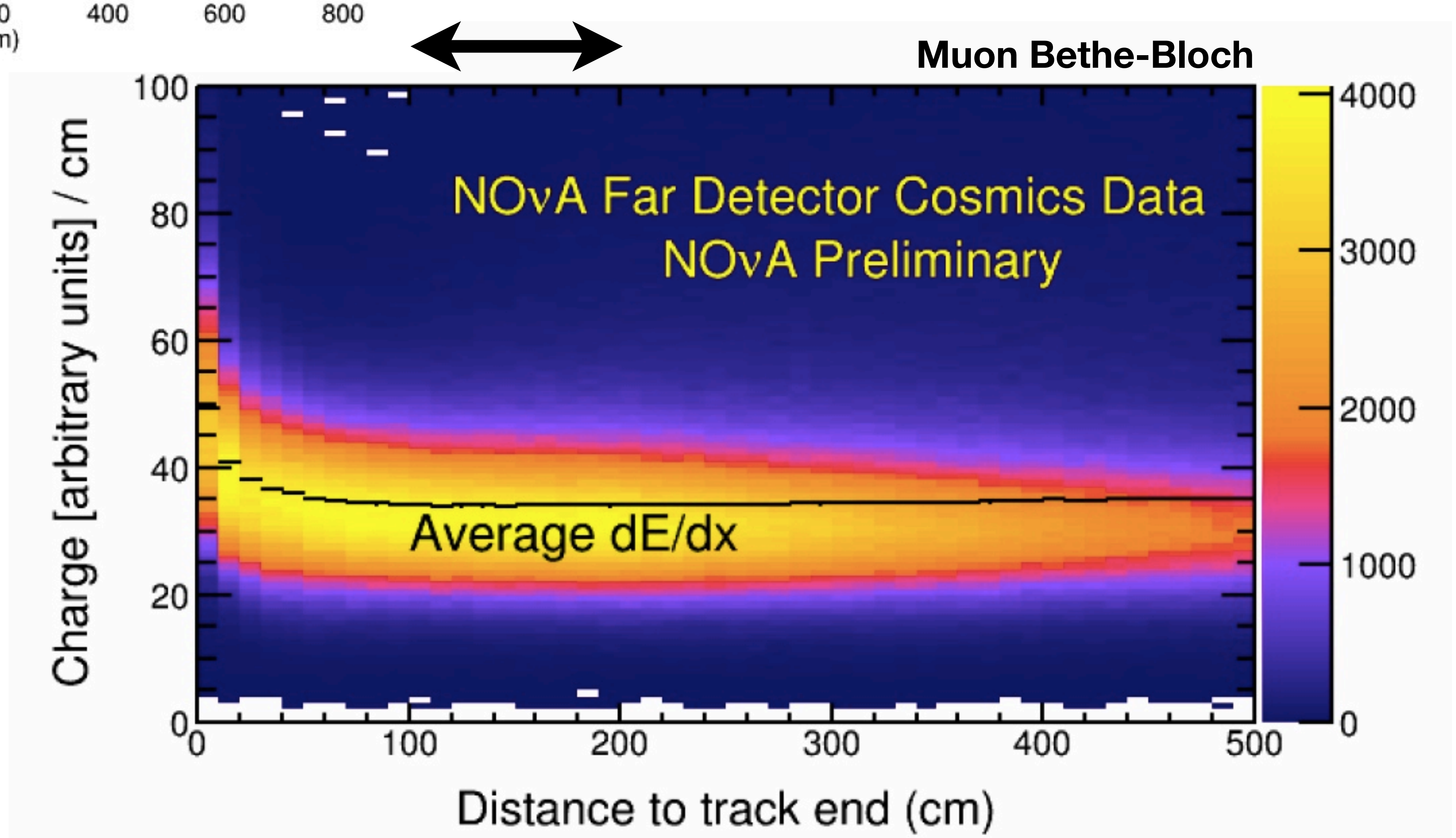
Run 11496
14k triggers
8 total live seconds



# Far detector calibration data

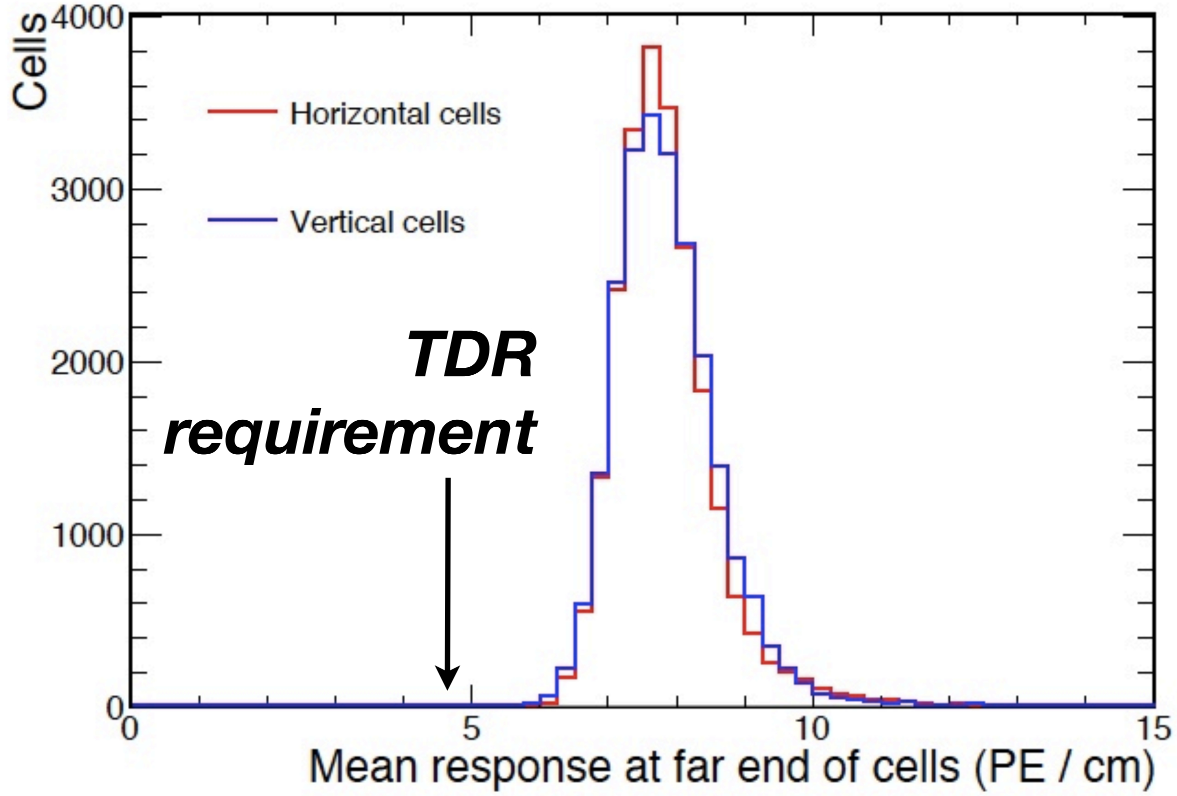



Use this region to set absolute energy scale

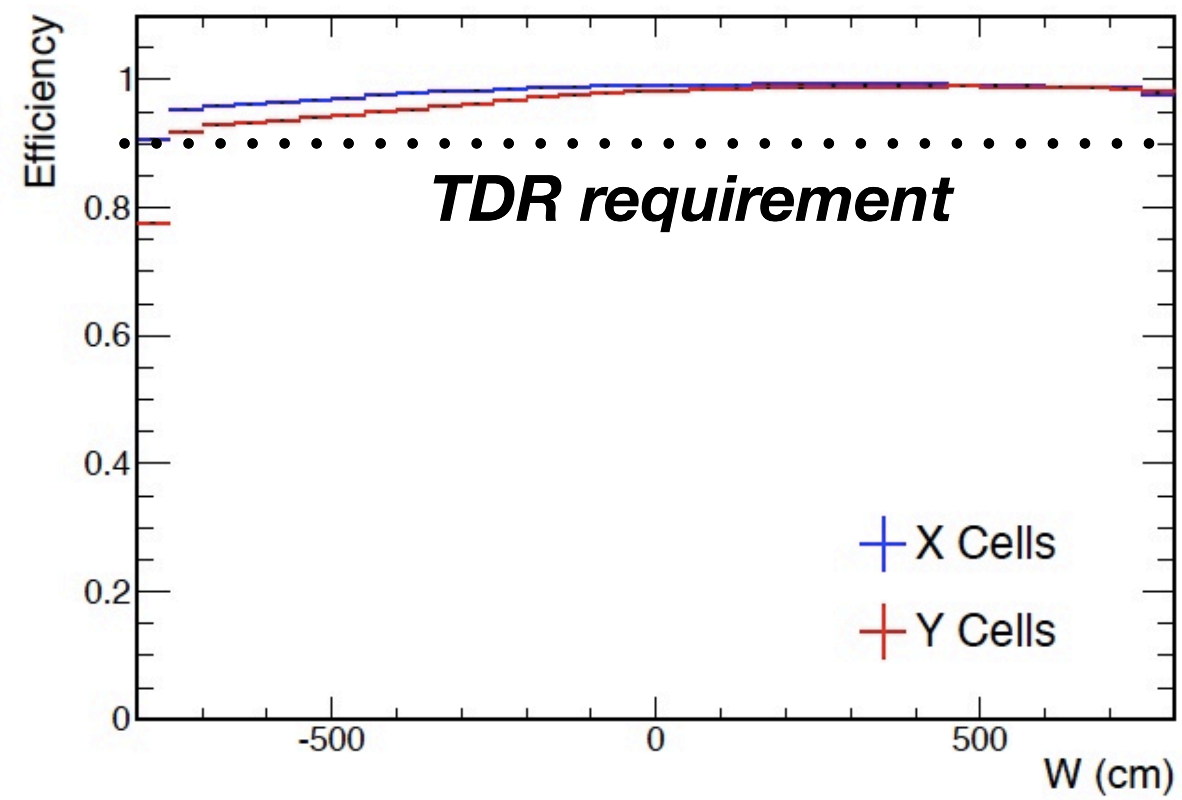


# Far detector performance

**Light yield at far end of cells**




**Efficiency for far end for 6-7.5 cm path length**




#photons/cm, transparency → Scintillator

reflectivity → PVC

capture efficiency, attenuation length → Fiber

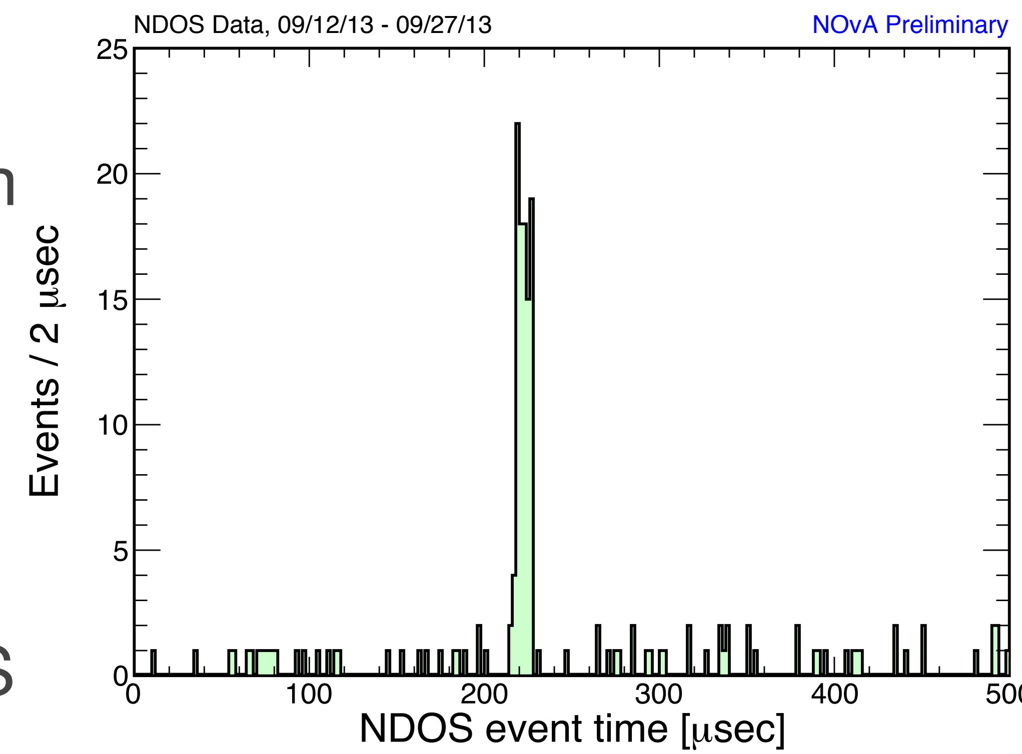
gain, noise, threshold → APD

Scintillator × PVC × Fiber × APD

meeting TDR specifications

# *Timing in the far detector / Seeing first neutrinos*

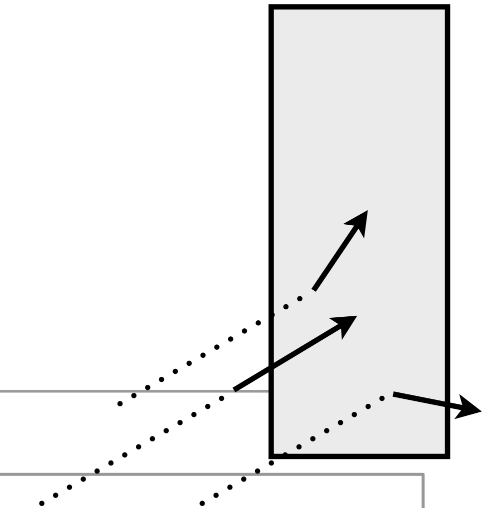
- Neutrino rates are low at far detector: 1/7th baseline detector mass, 1/3 of baseline beam intensity - more on next page.
- Using our prototype detector on the surface (NDOS) we are able to see a neutrino timing peak in every day of data
- Far detector is delayed with respect to NDOS by 2700 µsec. Expect to see neutrinos in same time window as NDOS.
- We have checked our ($T_{\text{far,NOvA}}$-$T_{\text{near,NOvA}}$) clocks against ($T_{\text{far,MINOS}}$-$T_{\text{near,MINOS}}$) and get the correct answer (810 km - 735 km)/c = 250 µsec
- Check underway against Rb atomic clocks transported from MINOS far detector.



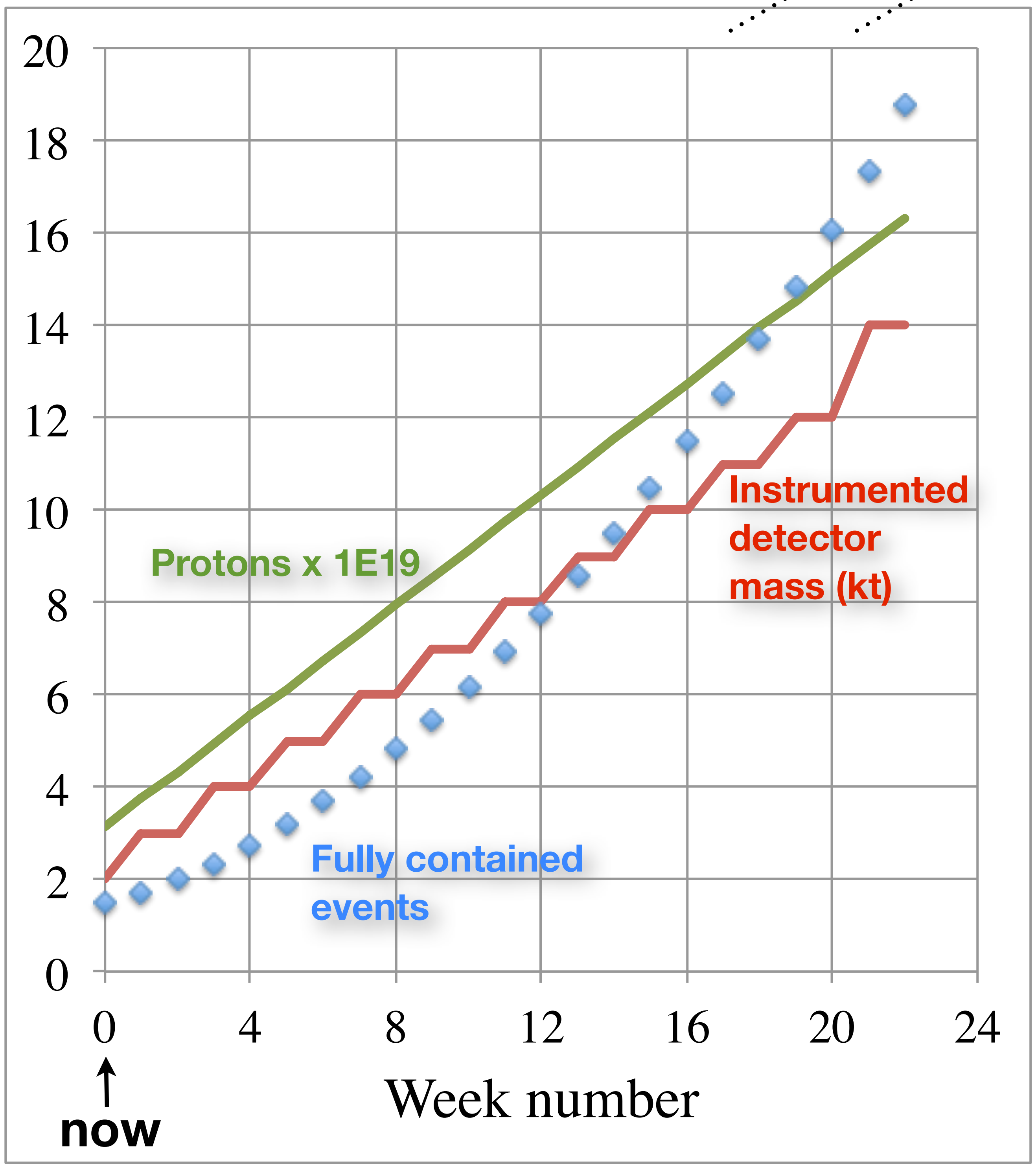

| Detector Locations (Table 2) | | | |
|---|---|---|---|
| Detector | $x$ | $y$ | $z$ |
| NDOS (NuMI System) | $-0.29$ m | 92.21 m | 841.76 m |
| NDOS (Booster System) | 13.88 m | 8.01 m | 641.40 m |
| Near Underground $3 \times 3$ | 11.57 m | $-3.64$ m | 993.35 m |
| Far | $11.03746 \times 10^3$ m | $-4.16264 \times 10^3$ m | $810.42232 \times 10^3$ m |

$$t_{\text{FD}} = 2703.56\ \mu\text{sec}$$
$$t_{\text{NDOS}} = 2.82\ \mu\text{sec}$$
$$\Delta t = 2700.74\ \mu\text{sec}$$

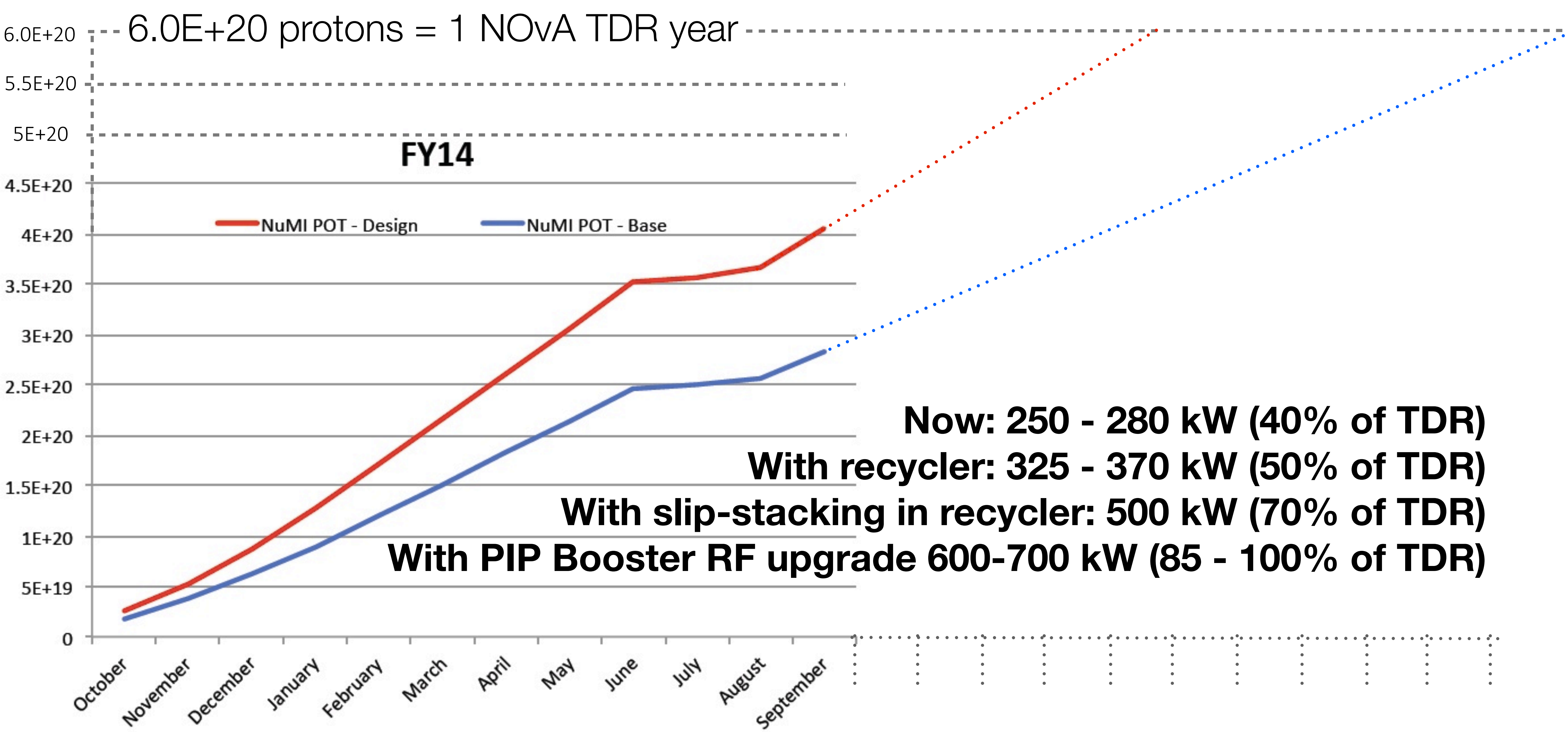
# *Seeing first neutrinos at far detector*



- We have been running 2 kt (14% of baseline 14 kt) at about 280 kW (40% of baseline 700 kW). Combined: 5% of baseline rate.
- We are running off-axis deliberately to maximize muon neutrino disappearance; event rate is not high to begin with.
- We expect 1 fully-contained event / kt / in the far detector every 4e19 POT
- Suppose we require two events to establish a timing coincidence. To be 90% sure of getting 2 need <n>=3.9.
- Active mass is now 3 kt and expected to grow at rate of 1 kt / week
- Should have a neutrino confirmation of far detector timing in ~6 weeks (90% CL)



# Protons




**Now: 250 - 280 kW (40% of TDR)**
**With recycler: 325 - 370 kW (50% of TDR)**
**With slip-stacking in recycler: 500 kW (70% of TDR)**
**With PIP Booster RF upgrade 600-700 kW (85 - 100% of TDR)**

Paul Derwent , Fermilab S&T Review, Nov 5-7 2013

# Summary

- Far detector construction has passed many milestones. Fully instrumented detector online this summer.
- Near detector construction has passed many milestones. Fully instrumented detector in spring.
- Beam intensity is ramping up. Need slip-stacking to get to 500 kW intensity. Baseline intensity of 700 kW will require PIP.
- We have lots of cosmic-ray data in hand and analyzed
  - Detector is performing to physics specifications
  - No major surprises in cosmic-ray rates. Analysis underway.
- Neutrino hunt is underway
  - We have several cross-checked on far detector timing
  - Limited by small statistics
  - Looking forward to having more detector and more beam